References

Link — Good online description of the ventilation calculation algorithm

Link — Online battery calculator

Link — Very nice example of how one would work this out on paper

Units

$cell := 1$ — Used for the number of cells in a battery

Constants

$k_{ExpLimit} := 1\%$ — 25% of the lower explosive limit of hydrogen Link

Utility Functions

$$r_G(T) := 7.607 \frac{mL}{min \cdot A \cdot cell} \cdot \left(1 + \frac{T - 25\ °C}{25\ °C}\right)$$

Hydrogen gas generation rate per cell per amp of overcharge current

$$r_G(0\ °C) = 0.42 \cdot \frac{L}{hr \cdot A \cdot cell}$$

I sometimes see this value cited.

$$r_G(25\ °C) = 0.01612 \cdot \frac{ft^3}{hr \cdot A \cdot cell}$$

I sometimes see this value cited.

$$R_G(I_{Overcharge}, N_{CellsPerBattery}, N_{Batteries}, T) := r_G(T) \cdot I_{Overcharge} \cdot N_{CellsPerBattery} \cdot N_{Batteries}$$

Analysis

Air Exchange Time

$$V_{Room} \cdot k_{ExpLimit} = R_G \cdot \Delta T_{Exchange}$$

The total volume of hydrogen that must be removed in a given time interval

$$\Delta T_{Exchange} = \frac{V_{Room} \cdot k_{ExpLimit}}{R_G}$$

The amount of time per air exchange in the room

Total Air Flow

$$F(k_{ExpLimit}, V_{Room}, I_{Overcharge}, N_{CellsPerBattery}, N_{Battery}, T) := \left| \begin{array}{l} \text{"Required Ventilation Rate"} \\ R_G \leftarrow R_G(I_{Overcharge}, N_{CellsPerBattery}, N_{Battery}, T) \\ \dfrac{R_G}{k_{ExpLimit}} \end{array} \right.$$

Rate of Air Exchange

$$R_{Exchange}(k_{ExpLimit}, V_{Room}, I_{Overcharge}, N_{CellsPerBattery}, N_{Battery}, T) := \left| \begin{array}{l} \text{"Required Air Exchange Rate"} \\ cfm \leftarrow F(k_{ExpLimit}, V_{Room}, I_{Overcharge}, N_{CellsPerBattery}, N_{Battery}, T) \\ \dfrac{cfm}{V_{Room}} \end{array} \right.$$

Worked Examples

Industrial Power and Battery Example **IPB Link**

Appendix Link

$T := 25\ °C$

$k_{ExpLimit} := 1.5\%$

$V_{Room} := 40ft \cdot 30ft \cdot 15ft = 18000.0 \cdot ft^3$

$N_{Batteries} := 20$

$N_{CellsPerBattery} := 3 \cdot cell \cdot 20$

They have an error in their example. They included the battery number twice.

$I_{OverCharge} := \dfrac{200 \cdot A \cdot hr}{20 \cdot hr}$

$R_{Exchange}(k_{ExpLimit}, V_{Room}, I_{OverCharge}, N_{CellsPerBattery}, N_{Batteries}, T) = 0.72 \cdot \dfrac{1}{hr}$ ✓

$F(k_{ExpLimit}, V_{Room}, I_{OverCharge}, N_{CellsPerBattery}, N_{Batteries}, T) = 214.9 \cdot cfm$ ✓

SBS Example

SBS Link

Appendix Link

$T := 0\ °C$

$k_{ExpLimit} := 1.0\%$

$V_{Room} := 30ft \cdot 60ft \cdot 9ft = 16200.0 \cdot ft^3$

$N_{Batteries} := 30$

$N_{CellsPerBattery} := 6 \cdot cell$

$I_{OverCharge} := \frac{100 \cdot A \cdot hr}{20 \cdot hr}$

$R_{Exchange}\left(k_{ExpLimit}, V_{Room}, I_{OverCharge}, N_{CellsPerBattery}, N_{Batteries}, T\right) = 0.08 \frac{1}{hr}$ ✓

$F\left(k_{ExpLimit}, V_{Room}, I_{OverCharge}, N_{CellsPerBattery}, N_{Batteries}, T\right) = 22.2 \cdot cfm$ ✓

Giant Battery Company Example

GBC Link

Appendix Link

$T := 0\ °C$

$k_{ExpLimit} := 1.0\%$

$V_{Room} := 80ft \cdot 60ft \cdot 30ft = 144000.0 \cdot ft^3$

$N_{Batteries} := 75$

$N_{CellsPerBattery} := 24 \cdot cell$

$I_{OverCharge} := \frac{450 \cdot A \cdot hr}{4 \cdot hr} \cdot 20\%$

Their charge current model is complex, but the final result is the same as the other examples. The assumes a 20% verchage that occurs over a 4 hour period. This is the same s assuming a 5% finishing current.

$R_{Exchange}(k_{ExpLimit}, V_{Room}, I_{OverCharge}, N_{CellsPerBattery}, N_{Batteries}, T) = 0.42 \cdot \frac{1}{hr}$ ✓

$F(k_{ExpLimit}, V_{Room}, I_{OverCharge}, N_{CellsPerBattery}, N_{Batteries}, T) = 996.8 \cdot cfm$ ✓

PocketEngineer2 Example

PocketEngineer2 Link

Appendix Link

$T := 0\ °C$

$k_{ExpLimit} := 1.0\%$

$V_{Room} := 40ft \cdot 30ft \cdot 15ft = 18000.0 \cdot ft^3$

$N_{Batteries} := 10$

$N_{CellsPerBattery} := 18 \cdot cell$

$I_{OverCharge} := 0.02 \frac{A}{A \cdot hr} \cdot 850 A \cdot hr$

$R_{Exchange}(k_{ExpLimit}, V_{Room}, I_{OverCharge}, N_{CellsPerBattery}, N_{Batteries}, T) = 0.25 \cdot \frac{1}{hr}$

$cf := F(k_{ExpLimit}, V_{Room}, I_{OverCharge}, N_{CellsPerBattery}, N_{Batteries}, T) = 75.3 \cdot cfm$

$SafetyFactor := 5$

$cfm_{WithSafety} := SafetyFactor \cdot cf = 376.6 \cdot cfm$ ✓

Textbook Example

Textbook Link

Appendix Link

$T := 25\ °C$

$k_{ExpLimit} := 1.0\%$

$V_{Room} := 8ft \cdot 12ft \cdot 9ft = 864.0 \cdot ft^3$

$N_{Batteries} := 1$

$N_{CellsPerBattery} := 24 \cdot cell$

$I_{OverCharge} := \frac{40A}{4}$ Assume that the rectiifiers fail and drive max current into the battery.

$R_{Exchange}(k_{ExpLimit}, V_{Room}, I_{OverCharge}, N_{CellsPerBattery}, N_{Batteries}, T) = 0.45 \cdot \frac{1}{hr}$

$cf := F(k_{ExpLimit}, V_{Room}, I_{OverCharge}, N_{CellsPerBattery}, N_{Batteries}, T) = 6.4 \cdot cfm$ ✓

Appendix

IPB Example

Hydrogen Concentration Worksheet

During the recharging process, a lead battery releases hydrogen and oxygen through the electrolysis of sulfuric acid. The beginning of gassing is determined by the battery voltage, but the amount of gas depends on the current that isn't absorbed by the battery and is used in the electrolysis. As the battery reaches its full state of charge, the acceptance of current becomes less and the liberation of hydrogen is more.
Four percent (4%) concentration of hydrogen is dangerous and has a potential for an explosion.
Generally, the maximum allowable concentration of hydrogen is 1.50% of the room's cubic footage. To keep the hydrogen concentration below 4%, adequate ventilation or proper air exchange of the room must be provided.

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Rate of Hydrogen Release
1 Ampere x 1 Hour x 1 Cell = 0.016 cubic feet / Ampere Hour / Cell
Battery Hydrogen Calculation
Ampere Hour x Finish Rate (percent) x Number of Cells x 0.016 Cubic Feet / Ampere Hour / Cell

Example:
Quantity = 20 Batteries
Type = 3DJ-200
Ampere Hour = 200 Ampere Hour
Battery Hydrogen Calculation
200 AH x 0.05 x 60 Cells x 0.016 Cubic Feet / Ampere Hour / Cell =
9.6 Cubic Feet / Hour / Battery x 20 Batteries = 192.0 Cubic Feet / Hour

Room Calculation
40' Long x 30' Wide x 15' High = 18,000 Cubic Feet
18,000 Cubic Feet x 0.015 (Maximum Allowable Concentration) = 270 Cubic Feet (Maximum)
Rate of Concentration Calculation
270 Cubic Feet (Maximum Allowable) ÷ 192.0 Cubic Feet / Hour = 1.4 Hours or 85 Minutes
Rate of Air Volume Removal
18,000 Cubic Feet ÷ 85 Minutes = 211.76 Cubic Feet / Minute
You will need at least one exchange of air per hour in the substation with the existing air conditioning system in order to NOT have a ventilation fan to exhaust battery gasses.

SBS Example

Battery Room Hydrogen Gas Ventilation Calculator

REQUEST A QUOTE

Click Here to go back the our SBS-H2 Hydrogen Gas Detector Page!

Lead acid motive power batteries produce hydrogen gas at 80% recharge point, making proper ventilation in the battery charging area extremely important.

Hydrogen gas is colorless and odorless, and is lighter than air, causing the gas to rise to the top of a building. The concentration of hydrogen in the air should be kept below 1% to reduce risk of explosion.

The calculator provided below is for reference only.

No. Cells in Battery	6
6-Hour Rated Capacity of battery in ampere-hours	100
Volume of Hydrogen produced during recharge	**0.44** *cubic feet*

Room Width	30	(ft.)
Room Length	60	(ft.)
Room Height	9	(ft.)
Total Volume of Room	**16200** *cubic feet*	

Volume of Hydrogen	**0.44** *ft. (Result from Step 1)*
Number of Batteries Stored in Room	30
Hydrogen Gas Produced per Hour	**13.27** *cubic feet*

Volume of Room	**16200** *cubic feet (Result from Step 2)*
Hydrogen Gas Produced per Hour	**13.27** *cubic feet (Result from Step 3)*
Max. percentage of hydrogen gas allowed	**1%** *(Industry Standard)*
Complete Air Exchange Every	**732.7** *minutes*

Volume of Room	**16200** *cubic feet (Result from Step 2)*
Complete Air Exchange Every	**732.7** *minutes (Result from Step 4)*
Fan Requirement	**22.11** *cubic feet per minute*

Giant Battery Company Example

Step 4: Determining Fan Requirement

Fan Size = R x 60 minutes ÷ V
(R) = Room cu. ft.
(V) = Ventilation required

144,000 x 60 ÷ 144.73 = 59' 697.36 cu. ft. per hour or 995 CFM.

The ventilation system should be capable of extracting 59,697.36 cu.ft. per hour or 995 CFM.

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PDF File

PocketEngineer2 Web Page

How to calculate ventilation requirements for a battery room?

Calculation Example: instant results

Instant results at your fingertips on-the-move with *battMV* program.

Example (in English units)
A battery room (40 ft x 30 ft x 15 ft high) contains 10 batteries. Each battery has 18 cells. The rated capacity of the battery is 850 Ah. Boost charging method is employed for charging of battery. The hydrogen concentration in the room shall be kept below 1%. Find the hydrogen concentration in the room, and ventilation rate required.
Ignore the volume occupied by the battery.

Instant results
No. of Cell/Battery = 18
No. of Battery = 10
Rated capacity of battery = 850 Ah
Charging current, Igas = 0.02 A/Ah
H2 release rate = 0.01474 ft^3/h
Hydrogen produced = 45.1044 ft^3/h
Nett Room Vol = 18000 ft^3
% of Hydrogen gas in room after 1 hour without ventilation = 0.2506%
Allowable Hydrogen = 1%
Safety factor =5
Airflow required = 372.11CFM
Room Air-change/Hr = 1.24

Textbook Example

Example 5.14 Determine (1) the hydrogen evolved during normal (float) and abnormal conditions and (2) the fan capacity to limit hydrogen concentration to 1% by volume during abnormal operation for the following system. Provide the answers in liters/hour and CFM for a cell temperature of 25°C (77°F):

Remote equipment enclosure: 8 ft (2.4 m) wide × 12 ft (3.7 m) long × 9 ft (2.7 m) high
48-V, 24-cell, 150-Ah battery
Rectifier capacity: 40 A (four 10-A rectifiers in $N + 1$ configuration, $N = 3$)
Equipment load 12 A

Solution The float current during normal operation is assumed to be 0.01 A/100 Ah × 150 Ah = 0.015 A. Therefore,

$$Q_H = 0.46 N_{\text{Cell}} I = 0.46 \times 24 \times 0.015 = 0.166 \text{ liters/h}$$
$$= 0.00027 \times 24 \times 0.015 = 0.000097 \text{ CFM}$$

During abnormal operation, the calculations give

$$Q_H = 0.46\left(\frac{I_{\text{Max}}}{4}\right)N_{\text{Cell}} = 0.46\left(\frac{40}{4}\right)24 = 110.4 \text{ liters/h}$$
$$= 0.00027\left(\frac{40}{4}\right)24 = 0.065 \text{ CFM}$$

To maintain a concentration no greater than 1% by volume,

$$Q_{\text{VentRate}} = \frac{Q_H}{G_{\text{Limit}}} = \frac{110.4}{0.01} = 11{,}040 \text{ liters/h}$$
$$= \frac{0.065}{0.01} = 6.5 \text{ CFM}$$

As a point of reference, a typical residential bathroom fan is rated 50 to 100 CFM.